

This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

+ *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.

+ *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.

+ *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.

+ *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at `http://books.google.com/`

THE

INDICATOR AND DYNAMOMETER.

Price Four Shillings and Sixpence.

47. 310.

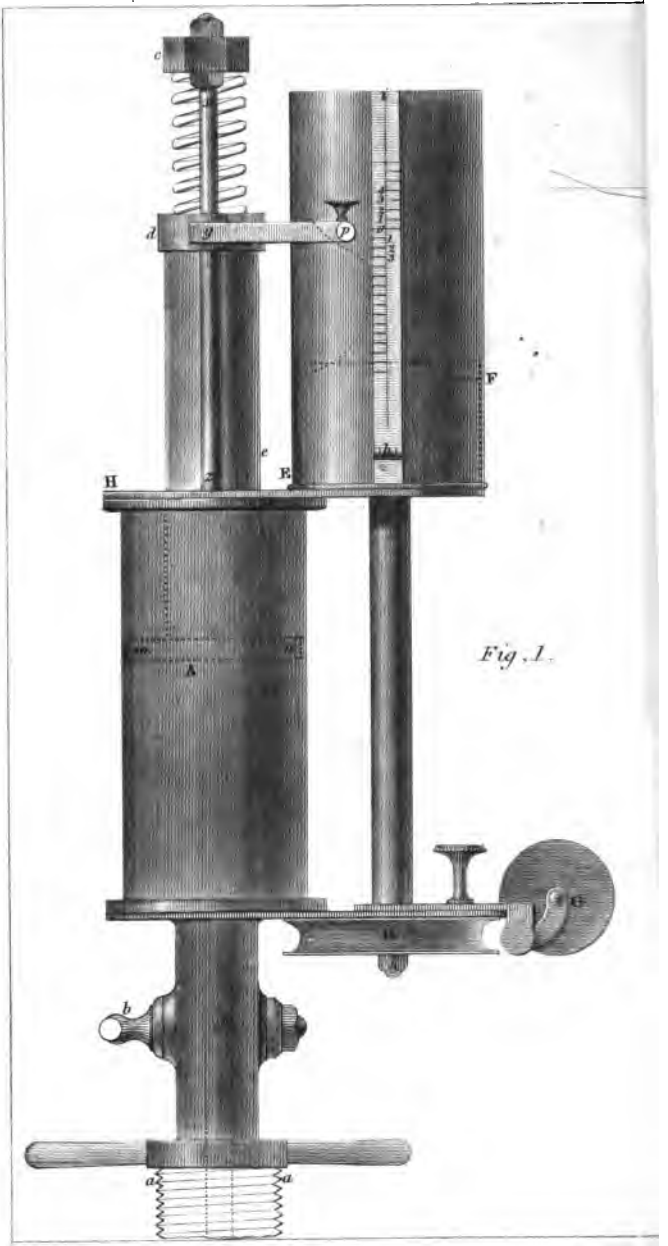


Fig. 1.

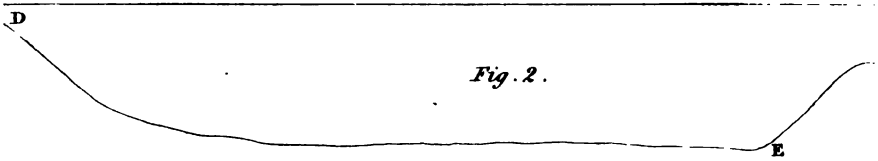
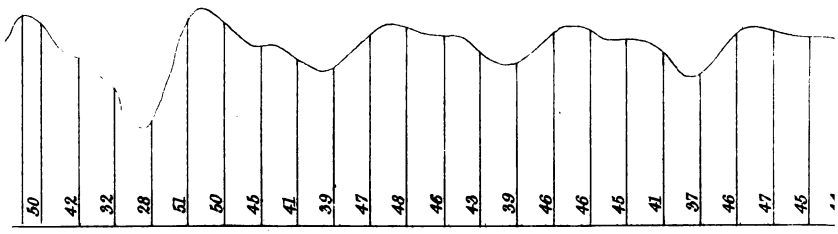


Fig. 2.

Fig. 4.



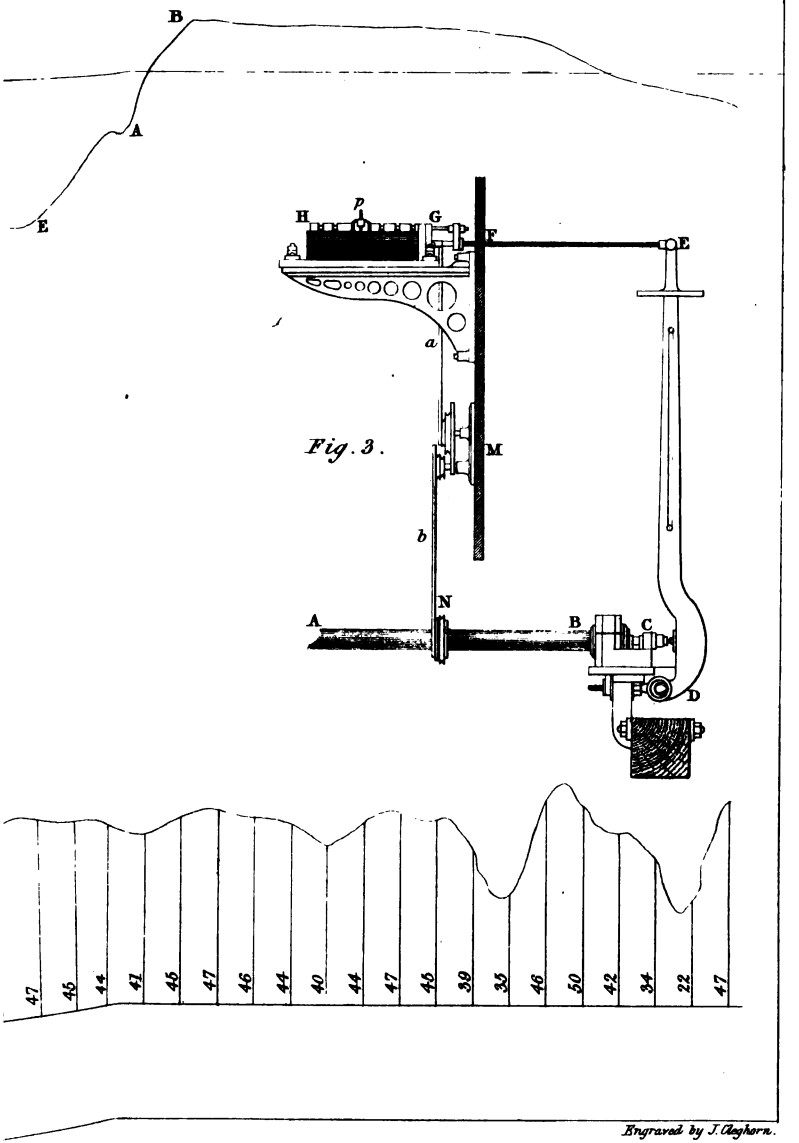


Fig. 3.

Engraved by J. Cleghorn.


BIBLIOTHECA · BODLEIANA

THE

INDICATOR AND DYNAMOMETER,

WITH

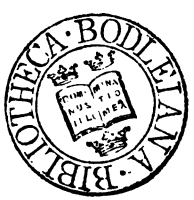
THEIR PRACTICAL APPLICATIONS.

LONDON:

HEBERT, 88 CHEAPSIDE;

AND WOODWARD, PORTSEA.

1847.



LONDON:
PRINTED BY LEVEY, ROBSON, AND FRANKLYN,
Great New Street, Fetter Lane.

INTRODUCTION.

THE object of the following pages is to extend the knowledge of two instruments connected with the Steam-engine, the Indicator and Dynamometer: the former of which is of universal application in land and marine engines; and the latter is applicable to those marine engines in which the screw is used as the means of propulsion.

The Indicator is one of Watt's inventions, upon which he was accustomed to place great reliance; and it may not, perhaps, be too much to say, that, in his hands, it contributed mainly to his successive improvements of the Steam-engine. After his patent had expired, and the Engine had become public property, the various makers, it seems, did not at first sufficiently value this little instrument; for we find Farey, in his work on Steam, complaining that Steam-engines had rather retrograded from neglecting it. However that may be, such is not the case now; for every engine-maker is careful to apply it, as the best means of testing the working condition of his engine: yet even now there are many classes of people connected with the Steam-engine, such as officers commanding steam-vessels, and engineers, to whom a fuller description of the instrument, and the uses to which it may be applied, will be

acceptable. Having felt personally the want of more practical information on the subject in existing works, it has been thought by the authors that the following pages will supply a deficiency, of which many have complained; and enable those who have not the opportunity of making experiments, to gain a more intimate knowledge of the Indicator; and it is hoped that some novel applications of the instrument will at the same time give it a degree of interest among those who are conversant with its ordinary details.

THOMAS J. MAIN, M.A.
Professor R.N. Coll. Portsmouth.
THOMAS BROWN, Engineer, R.N.

THE INDICATOR.

THE Indicator appears to fulfil two distinct and very important ends.

1. It enables us to discover whether there are any defects in those parts of the machinery by which the steam is admitted to the piston; for instance, it indicates whether the slides are properly set, or leaky; whether the stops on the intermediate shaft are properly placed; whether the steam-ports are large enough; and, consequently, whether a different arrangement of the working part of the machinery would be advisable. In fact, in the hands of a skilful engineer, the Indicator is as the stethoscope of the physician, revealing the secret workings of the inner system, and detecting minute derangements in parts obscurely situated.

2. It discovers, at any instant of time, and under any given circumstances, when it may be desirable to apply it, what is the actual power of the engine.

We will first give a description of the instrument, and then proceed to its various uses.

Plate I. fig. 1, is an external view of the Indicator, as constructed by Messrs. Maudslay and Field, having half the dimensions of the original in every respect. The dotted lines are intended to shew the internal parts. *A* is a hollow cylinder, whose upper end *EH* is open; the lower end being intended to fit into an orifice in some part of the engine (generally the top or bottom of the cylinder) by means of the screw *a a*: *b* is a stop-cock, by which, when the instrument is attached, we can, at will, make or cut off

a communication with the internal parts of the engine. Within the hollow cylinder *A* is a piston *mn*, packed and fitting steam-tight.[1] Let us suppose, for perspicuity, the instrument to be in communication with the *top* of the steam-cylinder. Then, when a vacuum is formed above the steam-piston, the atmospheric pressure will force down the piston of the Indicator, and it will remain at its lowest position till fresh steam enters; but it would immediately (unless prevented), on receiving a new impulse, be blown out of the open top *HE*. To prevent this, and at the same time to enable us to measure the force of the steam, a spiral spring presses with its lower extremity against the surface of the piston, while its upper end rests against the fixed cross-piece *c*. By this arrangement, the pressure of the steam will always vary, as the place of the piston varies; for it is a mechanical fact, that the tension of a spring varies as the extension. Hence the greater the pressure of the steam, the more the spring is compressed; and, on the contrary, as the steam loses its elastic force, the spring expands, and the piston descends. So that, to get a clear idea of the instrument, conceive the piston to be acted on by opposing forces: on the lower surface by the pressure of the steam (continually varying), and on the upper surface by the pressure of the atmosphere (constant), and by the force of the spring, varying so as to balance the steam-pressure. Now, as the steam-force is perpetually varying, it follows that the piston-tube (*de*) will be continually rising or falling. If a pencil (*p*) be attached to the upper end of this tube (*de*) in which the spring works, it will describe a vertical straight line on a piece of paper

[1] In practice this piston must not be packed *over-tight*, for fear of increasing the friction and preventing the free motion of the pencil; but the defect, if any, must be remedied by keeping melted tallow or oil on the upper surface.

brought into contact with it. This, however, is not sufficient for our purpose. It would, after it was traced, tell us the maximum and minimum pressure during the stroke; but the pressure *at any particular portion of the stroke* would still be undetermined. We must, therefore, have some plan similar to that adopted in other cases where the vertical motion of a pencil under particular circumstances is to be *registered.* In all such instances, the paper on which the variation is to be laid down is drawn horizontally at a certain rate. If, for instance, we were desirous of recording how the pressure varies with the *time*, the paper must be drawn *uniformly*, by connecting it with clock-work, or some other apparatus for giving an *uniform* motion. But this, however, is not usually the desideratum in the steam-engine. Our object is here to have represented before our eyes the variation of the pressure for every portion of the stroke of the piston; and this is contrived as follows: the paper is wrapped round a cylindrical barrel *C*, which is brought back against a stop, by a strong watch-spring contained in the box *EF*. A string passes round the pulley *D*, and is led away through a fair-leader *G*, to some part of the engine having a similar motion to the piston cross-head, only much reduced; by which means the watch-spring and the string are always opposing each other. As the piston rises, the barrel will be pulled from left to right; and, on the contrary, as the piston descends, the string having a tendency to slacken, the barrel will, by the force of the spring, be brought back from right to left. At *p* is the pencil attached to the upper end of the tube (*dg*), and rising and falling with the Indicator-piston. It can be brought into contact with the paper on the barrel *C*, or removed from it, at will, by means of the joint at *g*. The rod *xz*, and another one on the opposite side of the cylinder, serve as guides to the piston.

The paper is kept on the barrel by means of the strip of metal *hi*, which also serves another important purpose. It will be seen that it is graduated throughout its whole length, beginning from zero, and proceeding upwards and downwards. Now this zero is the level at which the pencil stands when the instrument is unconnected with the Steam-engine, and therefore acted on by the atmospheric pressure above and below the piston. The pencil will be seen at this level in the figure. If the barrel be made to revolve under these circumstances, a horizontal line will be traced out. This is called the atmospheric or zero line. And, therefore, the pencil will also be at this level whenever the steam, taking the place of the atmosphere *below* the piston, exerts the same pressure: and, consequently, wherever the diagram cuts this horizontal line, the pressure of the steam is 15lbs. on the inch;[1] when on the level of the marks 1, 2, 3, &c. above this zero, the pressure is 16, 17, 18, &c.; and when on the level of the marks 1, 2, 3, &c. below this, the pressure is 14, 13, 12, &c.

The remainder of the subject is put in the form of question and answer.

Should the atmospheric line be drawn before the diagram is taken, or should it be done afterwards?

It should not be taken till afterwards; because, as the parts become warm by the steam, slight variations occur in its position, depending principally on the alteration in the force of the spring; and since this line serves as the origin from which the pressures are dated, it is necessary to have it laid down as correctly as possible.

What is the use of the small hole (*m*) in the side of the stop-cock (*mb*)?

It serves to let the air into the cylinder (*A*) when the

[1] More strictly, 14·75 lbs., or a quantity differing from this slightly, according to the state of the weather.

steam is cut off by the stop-cock, and thus enables us to take the atmospheric line; it enables the stop-cock to perform the office of a four-way cock; for by turning it in one direction we allow the steam to enter, and exclude the external air; and by turning it in the opposite direction, we admit the air, and exclude the steam.

Being provided with an Indicator, how would you proceed to get a diagram?

First, look out for some part of the engine whose motion is proportioned to that of the steam-piston;[1] taking care that the space moved through at that part shall be somewhat less than the circumference of the traversing barrel: that is to say, whatever be the diameter of the traversing barrel, let the movement of the part you are looking for be not greater than *three* times this diameter. Fasten a string firmly to this point, and have a traversing loop in the loose end of the string; it must be of such a length that it may be connected with the string passing round the pulley of the Indicator. Then close the stop-cock of the Indicator, and fix it by the screw (*aa*) to some orifice previously prepared in the top or bottom of the cylinder.[2] Insert the pencil you intend to use in the small hole (*p*) made for its reception, and clamp it there. The pencil should be hard, and have a fine point, to give as clear and distinct a line as possible.

[1] That is to say, when you are wishing to find how the *pressure* varies with the *stroke* of the engine.

[2] If the top of the cylinder be chosen, the orifice for the grease-cup will generally answer the purpose. In some cases a pipe leads from the top to the bottom of the steam-cylinder, and the Indicator is attached to this pipe. It is provided with stop-cocks, so that when once fixed the arrangement is very convenient for taking two diagrams almost simultaneously from the upper and lower part of the cylinder. The only objection to it seems to consist in the tendency of the steam to condense in the pipe. For this reason it is advisable to have the Indicator as close to the cylinder as possible.

Those used for drawing-instruments, and marked HHH, are probably the best. Have some pieces of clean writing-paper provided, long enough to be brought round the traversing barrel, and overlap about an inch. Wrap a piece smoothly round the barrel, and fix it by means of the clasp (*ih*) containing the scale. Then tear away all the surplus paper, and examine what remains, to see if it be quite smooth: for if there be any ridges, the curve will have an irregular appearance, and might lead us to suppose some of the gear for working the slides had become loose, or much worn. Next wind the Indicator-string round the pulley of the barrel, *D*; and connect the hook at its extremity with the loop of the string attached to the engine. Adjust the string by means of the running loop, till you are satisfied of the motion of the barrel; allowing it to make nearly a whole revolution, but examining it most carefully to see whether it becomes slack, or overtaut. The stop-cock (*b*) may now be opened wide, and the Indicator-piston will immediately start into motion: the piston must be well lubricated, to reduce the friction as much as possible, and at the same time to prevent leakage. Let the instrument work for a few seconds, to allow it to become thoroughly heated; and when it has arrived at the same temperature as the steam-cylinder, it is in a fit state to trace its diagram. When satisfied of the working of the machine, take hold of the pencil when it comes to the *bottom* of its stroke, and bring it gently into contact with the paper. This part of the operation requires some practice; for if the pencil be allowed to come forward too rapidly, the spring at *g*, by which it is pressed against the barrel, will break the point; and again, if held too long, the force of the steam, suddenly acting on the machine, will tear it out of the hand, or break the holder. When left to itself, it will trace out its curve on the paper. As soon as it has made a complete

circuit, let the pencil be withdrawn from the paper (being again careful to take hold of it when at the *bottom* of its stroke). In order to have the line distinct, the pencil should not go over the same ground twice. Shut off the stop-cock, and the piston will become stationary, both sides being acted on by the pressure of the atmosphere. Bring the pencil again in contact with the paper, and as the barrel traverses, the atmospheric or zero line will be drawn. The operation is now complete, as far as the curve is concerned. Withdraw the pencil once more, unhook the line, and take off the traversing barrel. Next take a fine-pointed hard pencil, and mark off upon the paper the scale of pounds, beginning with the atmospheric line, and proceeding upwards and downwards. After taking the paper from the barrel it is completed by writing on it the date of the month, the name of the ship, that of the engine (whether starboard or port), top or bottom of cylinder, as the case may be, the number of revolutions, the pressure of steam by steam-gauge, and of condensation by barometer-gauge.

Why is it important to have a running loop, or other means of shortening or lengthening the string attached to the Indicator?

Too much attention cannot be paid to this circumstance. If too much strain be brought upon the string it will stretch, and if the string be too long it will become slack; and in either case the barrel will be stationary for a small interval while the steam-piston is moving, and the curve will not be a true indication of the motion. Indeed, if proper attention be not paid to this point, the diagram may turn out very different from what it ought to be. The corners of the figure will be sharper and better defined, and consequently those little faults of the engine, which it is our object to discover, will be hidden.

Do the pressure of the steam and the state of the vacuum on the diagram correspond with the boiler-pressure and condenser-vacuum?

No; the result will always be less. The difference will depend on the size of the ports, and the work the engine has to do; the distance the steam has to travel, the impediments it meets with in its passage from the boiler to the cylinder, and from the cylinder to the condenser.

Is it necessary to take a diagram from the top and bottom of the cylinder; or does the diagram taken from the top give us what is going on below the piston?

The diagram taken from the top of the cylinder shews only the pressure and vacuum on the upper surface of the piston, and therefore cannot indicate what is going on below the piston. If our object be merely to calculate the horse-power of the engine, and it be in tolerably good working condition, it is not of much consequence whether the diagram be taken from above or below; but if the actual state of the engine be required, it is necessary to examine into what is passing both above and below the piston, because the errors in one part may have no connexion with the errors in another. This will be the case if the slide is too long, or too short, so that the upper part may be properly covered, and the lower one disarranged; or the upper slide may be steam-tight, and the lower one leaky; and if the Indicator be applied to top and bottom, it will detect all these inaccuracies, and prevent our attempting to improve the working of one end, to the detriment of the other. It ought to be remarked here, that in unbalanced engines the diagram from below the piston is generally superior to the other; because, since the steam has more work to accomplish, the piston does not run away from the steam so readily, and in consequence, the steam-pressure is better

maintained; and there is generally a little more lead to the slide, to allow a freer ingress to the steam. And, therefore, if great accuracy be required, the mean of the top and bottom diagrams should be taken, for the horse-power.[1]

To what part of the engine should the string, carrying the running-loop, be attached?

It must not be attached to any part indiscriminately. Generally speaking, we wish to obtain the pressure of the steam for different portions of the stroke of the piston; therefore, the string must be fastened to some part of the engine having a stroke proportioned to that of the piston, only much reduced. The part selected must be as near the Indicator as other circumstances will permit; for the greater the distance, the longer the string, and consequently the greater is the chance of error from its stretching. Caution must be used also to prevent the string from slipping on the rod to which it is attached. One of the best contrivances for giving a free and proper motion to the string is to fasten a wooden-pulley to the radius-shaft,[2] to the groove of which the fixed end of the string can be connected. It

[1] We ought further to remark, that there is a difference between the motion of the slide in the up and down stroke. When the center of the eccentric has reached that part of its orbit farthest removed from the slide, the motion of the slide is slowest; and when at that part nearest to the slide, the slide's motion, though slow, is comparatively quick. But at such times the piston is moving very quick, and consequently in the former case, the steam line is farther extended than in the latter. This will therefore help to account for our getting a better diagram from the top of the cylinder of a beam engine and from the bottom of a direct engine; and the difference becomes more marked in engines having a short connecting rod. This is fortunate; for it assists in balancing the engine.

[2] In Maudslay's direct engines a pin can be fixed on the main center of the air-pump beam. In Seaward's direct engine the string may be attached to the *center line* of the radius-bar.

will be necessary, in most cases, to make use of fair-leaders for the purpose of conveying the motion from the part chosen to the Indicator; and due regard must be paid to this, to ascertain whether the motion of the engine will be fairly represented by the Indicator.

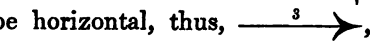
What directions may we, *à priori*, expect the pencil-diagram to assume under given circumstances?

Bearing in mind that all *vertical ascending* motions are caused by an *increasing* pressure of the steam, and that the *descent* of the pencil is the consequence of the elasticity becoming diminished; and again, that as the traversing barrel revolves from left to right, the piston is descending;[1] while, on the contrary, as the pencil moves from right to left, the piston is ascending;[1] hence, we shall arrive at the following general conclusions:—



1. If the motion of the pencil be vertically upwards, as at 1, the steam-pressure is *increasing*, but the piston is *not* moving.

2. If the motion be downwards, as at 2, the steam-pressure is *decreasing*, but the piston *not* moving.

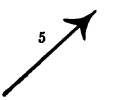
3. If the line traced be horizontal, thus, 

the steam-pressure *does not vary*, but the piston is *descending*.[1]

4. If the line be thus, 

, the steam-pressure *does not vary*, but the piston is *ascending*.[1]

5. If the line run as at 5, the steam-pressure is *increasing*, and the piston is *descending*.[1]



[1] This will be the case in one engine, but not necessarily so in another engine; and moreover, if the string be led in another direction the reverse will happen; but this the practical man can correct for himself according to circumstances, and substitute *ascending* for *descending*, and *vice versâ*.

6. If the line run as at 6, the pressure is *decreasing*, and the piston *descending*.[1]



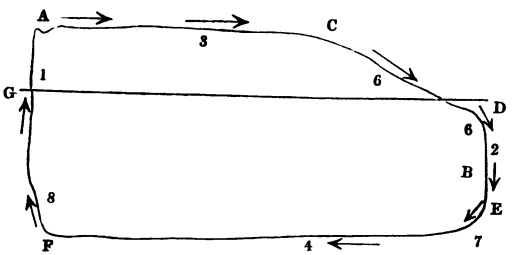
7. If the line run as at 7, the pressure is *decreasing*, and the piston *ascending*.[1]



8. If the line run as at 8, the pressure is *increasing*, and the piston *ascending*.[1]



Refer to the accompanying diagram, taken from above the piston of H.M.S. Bee, and explain it.



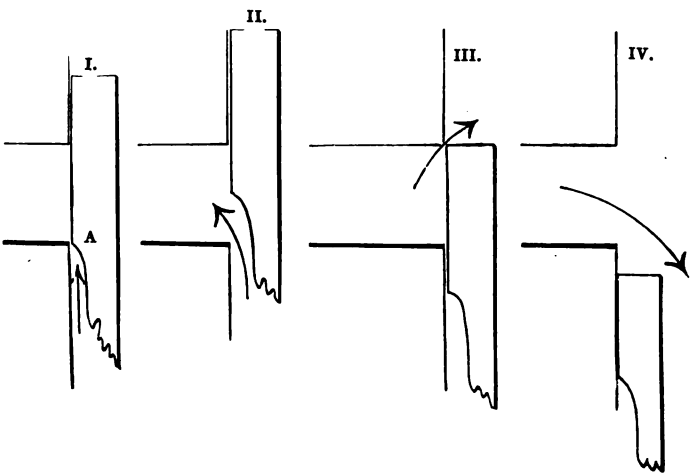
First, we will put numbers round the diagram, in conformity with the principles laid down in the last paragraph. Then, supposing the pencil to commence at *A*, and trace out the curve in the direction of the arrows, we see that the steam preserves its first and highest pressure for a considerable portion of the stroke, viz. from *A* to *C*; from *C* to *B* the downward stroke continues; but the steam rapidly loses its pressure, although at a variable rate, decreasing rapidly at *D*. At *B* the motion of the piston ceases; but the steam continues to fall, till at length the pencil moves back nearly horizontally for some space,

[1] See note on preceding page.

shewing the pressure to continue invariable, although the piston is rising. At *F*, however, 8 shews the steam-pressure to increase rapidly and suddenly, the piston still ascending; till, as this oblique line merges into the vertical one at *G*, we perceive that the piston has arrived at the upper end of its stroke; and the fresh influx of steam drives the pencil up to *A*. From this point the pencil will retrace the same curve. *GD* is the atmospheric or zero line.

We will now illustrate this curve, by what is going on within the engine.

When the pencil is at *G* (or it may be rather before arriving at *G*) the slide is in the position represented in fig. 1. and is rising; so that the steam is about to enter the



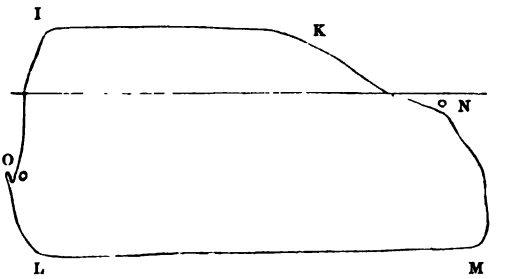
cylinder. Now this will take place, as the diagram shews, very slightly before the upward stroke of the piston is accomplished; and, since the piston and slide are both on the ascent, the lower edge *A* will have ascended a trifling space when the piston is at its highest. This slight space, though trifling in amount, is important in its results on the work-

ing of the engine. It is denominated the *lead* of the slide. As the piston descends the valve rises, and the admitting orifice becomes larger; so that although the piston is gaining speed in its downward course, yet in well-contrived engines the first pressure is continued, as we find in the diagram, through a considerable portion of the stroke.

The slide, however, has already begun its downward motion; and when the pencil arrives at *C*, it has returned into the position it had in fig. I. It is clear that as it continues to descend, no more steam can be admitted; whatever the cylinder contains will remain pent up; and as the piston continues to move downwards, the steam relaxes its force, and we trace a corresponding depression in the diagram from *C* to *D*. But a still greater change is to be expected before the piston arrives at its lowest place. Ere that happens, the slide will have come into the position shewn by fig. III.: for it is found to be disadvantageous to allow the steam to be kept in the cylinder till the end of the stroke; because the entering steam at the reverse stroke would meet with so much opposition, till the vacuum on the opposite side had become tolerably good, that the equability of the motion would be much affected. This being granted, we see that the port will be open for eduction before the end of the stroke: consequently a rapid fall in the curve takes place at *D*. Moreover, the slide continues to fall, not only after the piston has come to the bottom, but evidently during the greater portion of the up stroke. Although, after a very short interval, from the great rate at which the steam rushes into a vacuum, the state of the vacuum is nearly unaltered, and but little different from that in the condenser; hence, after turning the right-hand corner, the pencil runs nearly horizontally. At *F*, however, the slide has returned to the position represented in fig. III., and is *rising;* the piston is also rising, and near

the top; consequently the steam that has not yet made its escape, is pent up; and becoming more and more compressed, the pencil rises rapidly, till, the fresh steam entering, it starts up suddenly to *A*, and retraces the curve.

The accompanying diagram, being taken from the same



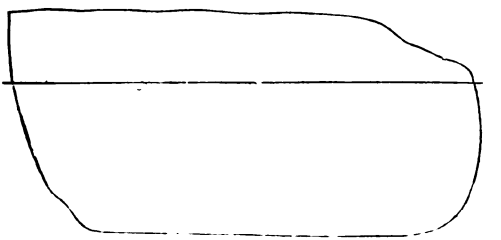
engine as that in page 15, in what respects do they differ, and what causes this difference?

We observe, in the first place, that the steam-line, *I K*, is shorter than in page 15, while the exhaust line, *L M*, is longer than in the latter; we infer, therefore, that the steam had a shorter time to come into the cylinder, and a longer time to make its escape. We observe, likewise, that the engine had made a considerable portion of its downward stroke before fresh steam was admitted. Now, these phenomena can be explained, by supposing from some cause the slide to be removed bodily below the place it had when the former diagram was traced. For let us refer to the series of representations of the slide before noticed. Thus the point *I* shews us the steam comes in later in this diagram than in the former; and the valve is rising; consequently its lower edge will be at some point lower than it would be in ordinary circumstances. Again, the point *K* of the diagram indicates to us that the steam is cut off again sooner; but the slide is descending; and

therefore, also, the lower edge is lower than it ought to be. Again, *N* being too far from the end of the stroke, we see that the exhaust takes place too early; in other words, the upper edge of the slide is too low. And lastly, the point *L* (where the cushioning commences) being carried too far to the left, shews us that too great an interval elapses before the upper edge of the slide reaches the upper edge of the port. And, consequently, every part of the reasoning proves to us the fact, that the slide is lower than should have been the case. Now, in pursuing our inquiries, we shall find this is caused by one of two defects, viz. either the slide-rod is too long, or the eccentric-rod is not of the proper length. But in seeking for the remedy, we must look to the slide-rod alone, because its length can be more easily adjusted than the eccentric-rod, by means of the nuts and screw by which it is fastened to the cross-head. The derangement of the engine, when the accompanying diagram was taken, was obtained by lengthening the slide-rod three-eighths of an inch. The projection at the point *O* remains to be noticed, although it would never appear, except in exaggerated cases, such as the one before us. It will be seen that the cushioning takes place from *L* to *O;* and consequently the pencil rises, because the steam is compressed: but the fresh steam does not yet enter; and therefore, as the piston descends, this steam, till now compressed, loses its elastic force, and the pencil drops; till at *o* a fresh supply enters, and the pencil starts up from *o* to *I*, taking a motion compounded of the motion of the piston and the pressure of the steam; for it is to be noticed that the line *oI* bends sensibly to the right; this arises from the increasing velocity of the piston, and is not observable in the standard diagram, except near the top, because the piston is all but stationary during the short time the steam is entering.

What would have been the effect, if the slide-rod had been shortened?

The opposite effects would have taken place; that is to say, the upper portion of the diagram would have been spread out, and the lower part contracted. The effect is shewn in the accompanying diagram, to obtain which the slide-rod was shortened three-eighths of an inch.

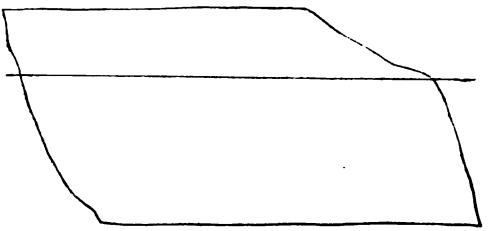


NOTE. If the whole slide be of the proper length, it is clear that when we get a faulty diagram, similar to that in page 18, taken from above the piston, the one taken from below it will be similar to the annexed figure, and *vice versâ*. Hence, therefore, we see one advantage of taking both a top and bottom diagram. But if the one diagram be similar to one of those just exhibited, and the other be satisfactory, the fault lies with the slide itself, and cannot be remedied but by the engine-makers. The only plan for the engineer is to divide the fault as equally as he can between the upper and lower parts, by lengthening or shortening the rod, according to circumstances. Moreover, we perceive an engineer should not be satisfied that he has done all, when he has obtained a good diagram from one end of the cylinder; because, if the fault lay with the slide, he would be improving one to the injury of the other.

What would be the effect on the diagram, if the stop on the eccentric were too far advanced?

All the motions of the slide, whether up or down, would

take place sooner than ordinary: that is to say, the cushioning, the introduction of fresh steam, the cutting off, and the exhaust would all commence sooner. The curve, therefore, instead of being like the standard diagram, will be similar to this, assuming somewhat of a lozenge-shape, the

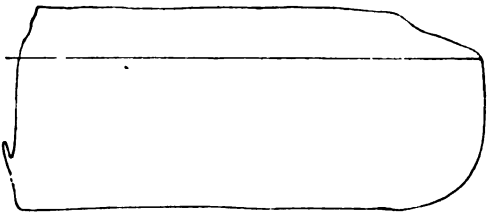


upper left and lower right corners being acute-angled, and the other two obtuse. Again, a little reflection will enable us to discover that similar defects will be exhibited in the lower diagram under these circumstances, and not opposite defects, as was the case when the slide or eccentric-rod was at fault.

Obs. This curve was obtained by inserting a piece of metal, half an inch thick, between the stop on the eccentric and that on the shaft.

How could it be ascertained, by inspecting the diagram, if the stop on the shaft were not sufficiently advanced?

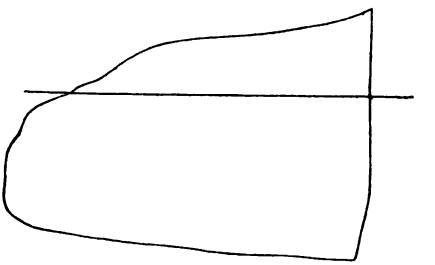
In such case, all the motions of the slide will be later than they would be in a well-constructed engine; consequently, all the upper part of the curve will be drawn towards the right, and all the lower part to the left. And, as in the former case, the same distortion will be observable if a diagram be taken from the lower part of the cylinder. Moreover, if the defect be great, we shall meet with the hump in the lower left-hand corner, similar to that before noticed. The diagram at the top of the next page was



taken after removing back the stop on the shaft seven-sixteenths of an inch.

If the ports of the cylinder, or the steam-pipe, be too small, how will it tell on the diagram?

Since the steam will not be able to enter or escape so freely as it ought, the pressure at first entrance will not be maintained for any length of time, and the vacuum will not be formed rapidly enough; the steam and vacuum lines will therefore lose their horizontality; as is easily discovered in the diagram here given, which was taken from one of our largest engines, afterwards altered by shortening the gab-lever.

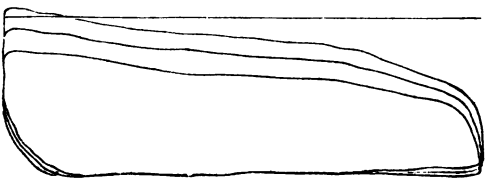


What kind of diagram is obtained by throttling the steam?

The upper line will rapidly decline, for the same reason that it would if the steam-pipe or the port were too small; and it will not be so high altogether as in ordinary cases. The vacuum-line, however, will be better than it would otherwise be; for since the quantity of steam admitted is

not so great, the speed of the piston will be reduced. But the exhaust-port is of the same size whether the steam be throttled or not; and, therefore, there is more time for the expended steam to rush through this orifice into the condenser; and consequently the vacuum-pressure in the condenser and in the cylinder will be more nearly equal, and better in both, than when the full power is set on.

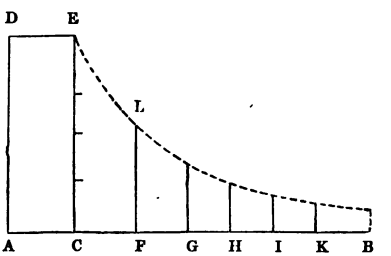
The accompanying diagram represents three diagrams



taken from the Bee's engine, the steam being throttled to various degrees.

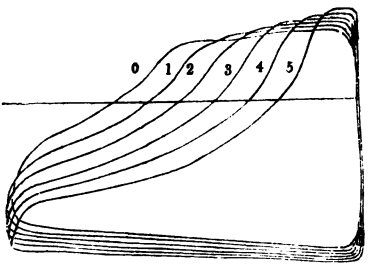
What sort of diagram would you expect if the expansive gear alone were used?

Let *A B* represent the whole length of the cylinder; and



when the piston has traversed the space *A C*, let the ingress of the steam be suddenly stopped. Then, from this epoch, the steam-pressure will decrease, and the pencil begin to descend. Now if the temperature of the steam be unaltered, the pressure will vary inversely as the space it occupies. Divide, therefore, the space *C B* into intervals

C F, *F G*, &c. each equal to *A C*; and therefore when the piston is at *F*, the space *A F* being *twice A C*, the pressure of the steam at *F* is *half* that at *C*; at *G* it will be one-third; at *H* one-fourth, &c.; and if lines be drawn through *C*, *F*, *G*, &c. parallel to *A D*, and of the length we have just indicated, making *C E*=*A D*, *F L*=half *A D*, &c., and through the upper extremities of these lines a free curve be traced, it will give us an idea of what we ought to expect. But since the slide-valve also acts, we shall have the modification this would produce too; for the slide-valve is placed between the expansive valve and the cylinder; it follows, therefore, that the effective volume of the steam, intercepted by the expansion-valve, is the whole of the space between it and the piston, and the slide-valve interposes an additional barrier when it begins to cut off the steam.[1] The case, therefore, is somewhat similar to what it would be if there were two expansion-valves, one nearer to the cylinder than the other, and the outer one acting first. This figure re-



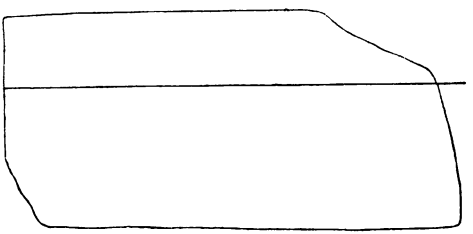
presents a series of diagrams taken from the same engine as that in page 22; here 0 gives the full steam without using the expansion gear; 1, that produced by the first grade of expansion; 2, that produced by the second grade; and so on. We must here remark, that in the interval that

[1] Except in engines fitted with Seaward's slides.

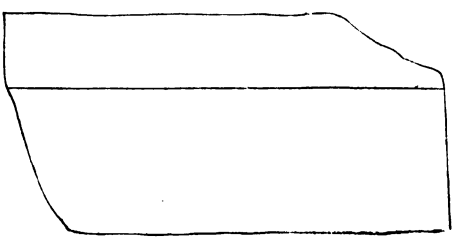
elapsed between taking the diagram in page 22 and the series here represented, the engine had been improved by shortening the gab-lever, and thus enlarging the aperture for steam and eduction. The effect will be observable by comparing the diagram marked 0, with that in page 22.

May we rest satisfied the engine is in good working condition when the general features of the diagram are satisfactory?

Not always. In the hands of an inexperienced person, the Indicator may trace an unfaithful representation of the condition of the engine. When the piston is near one end of its stroke, if an undue strain be brought on the string, it will stretch, and the Indicator-barrel remaining stationary while the steam is entering, the pencil will have a vertical ascending motion, such as is represented in the figure. On the other hand, if the barrel come back against

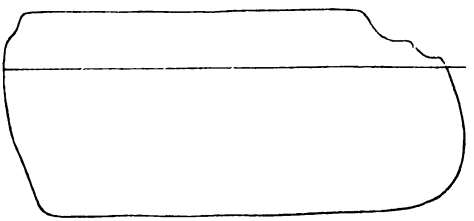


its stop before the opposite stroke is accomplished, the pencil will fall vertically, as in this figure. These two



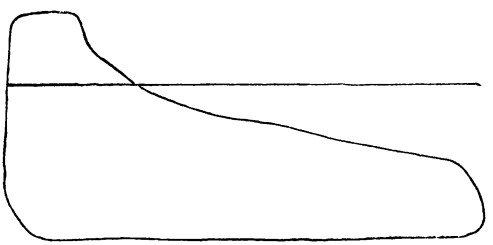
figures ought to have been precisely similar, the only cause of difference being the accident of the string.

To what cause must we attribute the series of steps in the right upper portion of the accompanying diagram?



This arises from the piston of the Indicator being packed over tight, on which account it descends by a series of jerks, as the steam-pressure relaxes.

Why does the steam-line in the accompanying figure



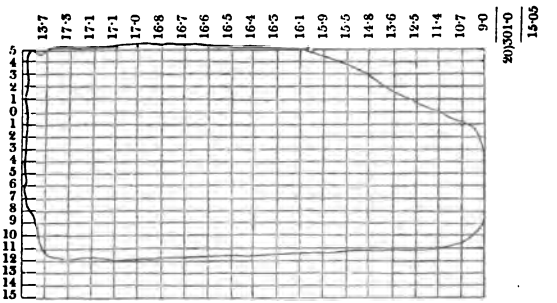
not descend so rapidly as in the imaginary curve spoken of in page 23?

Because the expansion-valve of the Bee, from whose engine it was taken, is leaky, and therefore does not entirely cut off the steam.

Shew how to ascertain the power of an engine by means of the Indicator.

This is the most accurate way of ascertaining the power of an engine; because, as may be seen, the diagram gives the pressure on the piston; and hence, knowing the number

of revolutions and the length of stroke, the labouring force can be ascertained. The mean pressure on the piston is obtained as follows: Divide the diagram by a series of equidistant vertical lines, as in the figure (the closer the better),



and, taking the horizontal line marked 0 as the origin, draw a series of other lines parallel to it at distances equal to the intervals corresponding to the scale of pounds on the Indicator. This being accomplished, if our object be only to form an estimate of the gross power, observe in the middle of each vertical space the number of pounds included between the steam and vacuum lines to tenths, which will be best done by taking the distance with a pair of compasses, and setting it off on the scale of pounds. Write these in their proper columns, as in the figure, along the diagram, and add them together. Then divide the gross result by the number of columns, and we obtain the gross average pressure on the one side of the piston during the up and down stroke. From this it is usual to deduct from 1lb. to 1·5lbs., according to the size of the engine, for friction; for small engines have more friction in proportion than a larger; then the result is taken as the effective pressure per square inch, acting *uniformly* during one whole revolution. Take now the diameter of the cylinder in inches, and square it; then multiply the product by ·7854, the result is the number of square inches in the

surface of the piston. Multiply this again by the pressure per square inch, as got from the Indicator, for the whole pressure in pounds on the surface of the piston. And if this be multiplied by the length of a double stroke, and finally by the number of revolutions, we shall obtain the work done by the engine. It is usual to divide this quantity by 33,000 (supposing this to be the number of pounds a horse would be able to raise one foot a minute); and the quotient is then called the horse-power of the engine. If there be two engines, as is usually the case in steamers, this quantity must be doubled.[1]

If it be necessary to find, *separately*, the value to be

[1] *Ex.* In the preceding diagram, let the number of revolutions be 38, and therefore the number of single strokes 76.

Then, since diameter of steam-cylinder = 20 inches,

$\therefore$ Diam.^{2} = 400
·7854

314·2000 sq. inches.

But pressure of steam = 15·05 lbs.
Deduction for friction = 1·50

$\therefore$ Effective pressure per inch = 13·55
314·2

2710
5420
1355
4065

Pressure in lbs. on piston = 4257·410
76

2554446
2980187

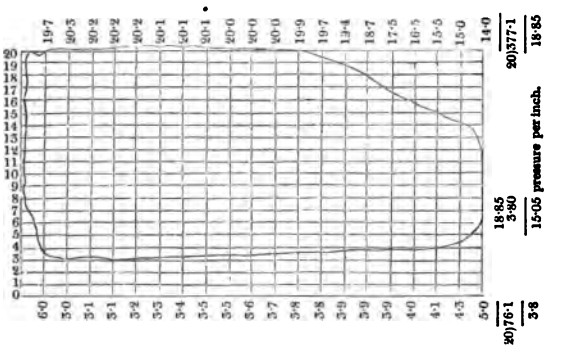
323563·16
2

33|000)647|126·32

19$\frac{3}{4}$ horse-power.

given to the steam and vacuum pressures, how is this to be effected?

To obtain this, we must get the actual pressure, and not the difference of pressure between the steam and vacuum lines. And therefore we might measure the height of the spaces above the atmospheric line, and the depth of the vacuum below it. But, in regard to the steam-line, a difficulty has to be surmounted, which would not easily be got over by practical men unaccustomed to analytical investigations. It is this; that part of the steam-line is usually above the atmospheric line, and part below it; and the results of the one must be subtracted from the results of the other. This is more particularly to be noticed in cases where the engine is working expansively, and a great portion of the steam-line is in consequence below the atmospheric line. The following suggestion will, however, get over the difficulty: consider the atmospheric line, as in the following figure,



to be 15lbs. (which is its actual pressure), and reckoning downwards, call the lines below it 14, 13, &c., till we come to 3, 2, 1, 0: the line marked 0 we will assume as that line from which the pressures are measured, and both the steam and vacuum line will be above this new zero line; and the

actual pressures of each will, by these means, be ascertained, and not the relative pressure, as compared with that of the atmosphere. In the preceding diagram, this second method of computation has been performed; the numbers on the left-hand side beginning from the absolute zero, and the figures along the top and bottom of the curve giving the steam and vacuum pressures respectively. The mean of the steam-pressure is 18·85lbs., and of the vacuum 3·8lbs. The difference is 15·05, as we obtained before.

How is the work done in one single stroke of the piston to be determined?

Let us suppose the piston to be descending; then the steam-pressure acts above the piston, and the vacuum-pressure below the piston; that is to say, the steam-pressure must be got from the top diagram, and the vacuum-pressure from the bottom diagram; and we must, therefore, make use of the method proposed in the answer to the last question. Thus, to obtain the mean pressure during the down stroke, take the steam-pressure from the top diagram, and the vacuum-pressure from the bottom diagram, and subtract the latter from the former. Again, to obtain the pressure during the up stroke, take the *vacuum*-pressure obtained from the *top* diagram, from the *steam*-pressure got from the *bottom* diagram. This seems to be the only correct method of arriving at the work done during the down and up strokes respectively.

How can the Indicator be employed for ascertaining the quantity of steam an engine uses?

Fix on any convenient part of the steam-line between that point where the steam is cut off and the opening is made to the condenser; that is to say, between the points *C* and *D* of the diagram, page 15. Observe, by counting the vertical spaces, what proportion the portion of the

stroke, as far as this point, bears to the whole length of the stroke. Notice also the pressure of the steam at this point. Then we shall have a certain fraction of the cylinder filled at each stroke with steam of a given pressure. If now the cubic contents of the cylinder be determined, and the number of times the cylinder is filled per minute, we shall have the quantity of steam of known pressure supplied to the engine per minute. Thus, suppose that in the Bee $\frac{9}{10}$ of the cylinder were filled with steam of 15lbs. pressure; then, since the number of cubic inches in the cylinder twice filled is 15079·6, the number of revolutions being 34 at the time of experiment, the whole number of inches in a minute = 51252·64, $\therefore \frac{9}{10} \times 512526{\cdot}4 = 461273{\cdot}76$, and the number of cubic inches of atmospheric steam in an hour $= 461273{\cdot}76 \times 60 = 27676425{\cdot}60$. But each inch of water is supposed to form 1711 cubic inches of steam at the atmospheric pressure, and therefore the number of cubic inches of water evaporated $= \frac{27676425{\cdot}6}{1711} = 16175$; and the number of gallons of water evaporated $= \frac{16175}{277} = 58$ nearly.

Now, if the theory be correct, this should be the quantity of water evaporated from the boiler, due allowance being made for condensation, &c. in the steam-pipe and passages. But this is far from being the case, for the number of gallons actually evaporated by the boiler was ascertained to be 108 gallons in the hour. We can do nothing more at present than state the discrepancy, and offer the following hypothesis to account for it. From the violence of the ebullition, the steam is in all likelihood not so dry as that on which careful experiments are made, as is frequently made manifest in boilers that "prime;" so that, even in good boilers, it is very possible for the steam to contain much more watery vapour than it would

if it were not so rapidly consumed. If so, an inch of water would not under these circumstances form 1711 cubic inches of steam under the atmospheric pressure, and might perhaps form only one-half that quantity, which would be requisite to give the proper number of gallons of evaporated water. It remains to be seen by future experiments whether this be the fact; and if true, it will throw doubt on the tables of relative volumes of steam and water contained in most works on the Steam-engine.

By what means can we determine the friction of the unloaded engine?

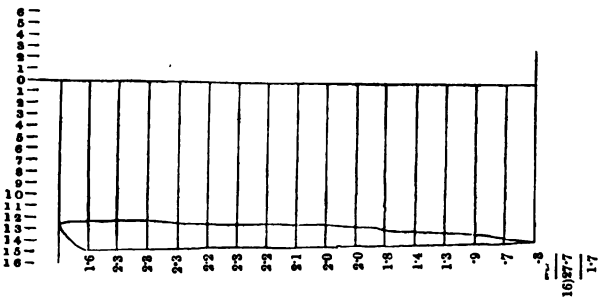
If we examine the effect of any machine at work, however simple, we shall find a certain amount of power is requisite to overcome the friction of the engine itself. Divest a common crane of its chain, or any load that may be upon it, and it will still be found that some force must be applied to give motion to the gearing itself; the amount of force depending on the materials used, the mode of fitting, and the quantity of gear set in motion. So it is with the steam-engine. A certain amount of power is required to overcome the friction of all its parts; and in this respect no two engines will be found alike, so much depending on the goodness of the workmanship, and the nice adjustment of the different parts.

Before proceeding with the method of ascertaining the friction of an engine by the Indicator, we would observe, that the greatest care and judgment are requisite in carrying out this experiment; let no one attempt it unless he see his way clearly; and there are many classes of engines in which the experiment ought not to be tried, especially direct acting engines; indeed, in all unbalanced engines it would be attended with serious risk, by giving the engine enough steam to work it without its load. The way, however, to proceed is this; the *communication valve* must

first be closed, because the engine requires an exceedingly small quantity of steam to work it when the paddle-wheels are disengaged. Then let the blow-valve be opened, to allow any steam that may happen to be in the steam-pipe to escape. The more the vacuum is vitiated before commencing the experiment, the safer it will be; for there is less liability of injury to the engine when first set in motion. In the Bee, it is found necessary to destroy the vacuum, before getting the diagram, by opening the blow-valve, to prevent the engine flying off at too great speed. The throttle-valve must be closed, and the paddles disconnected. After slightly opening the communication and throttle valves, the slide may be opened gradually and cautiously, to admit the steam to the piston, and the injection must be let on as carefully as possible. Work the engine a few strokes by hand, and then let it be thrown into gear, and regulate the working by the throttle and communication valves; the object being to give the engine the same number of revolutions without the paddles as it usually has with them; taking care to have the condenser of the same temperature as in the ordinary working state of the engine.[1] The Indicator having been previously fixed and adjusted, let a diagram be taken: it will be widely different from that when the load is on. Both the steam-line and vacuum-line will be much below the atmospheric line. The diagram

[1] We would strongly advise the insertion of the bulb of a thermometer in the condenser of every engine, in addition to the barometer-gauge. The bulb must be entirely within the condenser, and the scale (at least that part of it which is above 50^0 or 60^0) outside, in the engine-room. The thermometer chosen for the purpose must be graduated higher than the temperature of the steam in the boiler, otherwise it will burst when the engine is blown through. It must be placed in some part acted on freely by the steam, but free from the splash of the injection water. When the engine is free from air it will then serve as a most delicate test of the vacuum. The temperature preserved should be about 100^0.

may then be taken off, and divided as in the former case. Let the result of this diagram be worked off in the same manner as the common diagram, and the amount is the work the steam has performed, or in other words, the friction of the unloaded engine. This has been accomplished in the subjoined diagram.



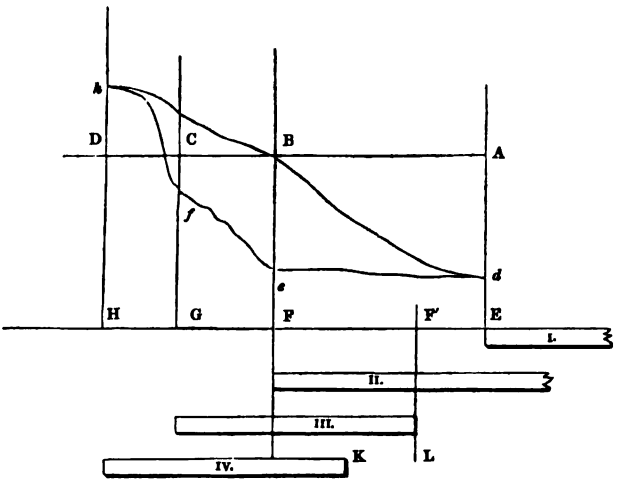
This is what is commonly subtracted from the gross result obtained under ordinary circumstances, and denominated friction; but it is manifest, that it is much less than the actual friction of the engine when turning the wheels; for the friction of every machine increases with its load; and moreover, the injection water, &c. raised by the air-pump increases likewise, and all this goes under the head of friction. The friction of large engines is less in proportion than that of smaller ones; in large engines it is usual to allow 1lb. on the square inch of the piston for friction, and in small engines from 1·5 to 2lbs.; and in most cases it would be better, except as a matter of experiment, to trust to this than to attempt the difficulty of ascertaining it.

What is meant by a *slide* diagram?

A diagram in which the Indicator-string is connected with the cross-head of the slide, and not with that of the piston; so that the horizontal motion of the pencil backwards and forwards corresponds to ascents and descents

of the slide, and *vice versâ*. And this process will give us many particulars of the slide, without the trouble of taking the engine to pieces for measurement. If the Indicator be applied to the upper end of the cylinder, it will give us information of the upper slide-face; and if to the lower end, of the lower slide-face. As was before stated, the string must be connected with some part having the motion of the slide; but generally it will be necessary to reduce the motion, because the stroke of the slide is more than the Indicator-barrel will allow; in small engines, such as that of the Bee, it may be attached to the cross-head direct. As was before remarked, so long as the pencil is moving from left to right, the slide is rising; and when moving from right to left, it is falling; and any rise or fall of the steam-pressure is due to the change of pressure in the steam, as in the common or piston diagram. Then the difference in the two cases would be this; that in the common case we have changes of pressure corresponding to motions of the *steam-piston;* and in the *slide diagram* we have changes of pressure corresponding to the motions of the *slide;* and the important thing to notice is, that every sudden change of pressure refers to some prominent epoch in the slide's motion; and consequently we are enabled to trace successively on the paper, the various positions of the slide from its lowest point as it cushions the steam, allows fresh ingress, &c., and finally arrives at its highest point.

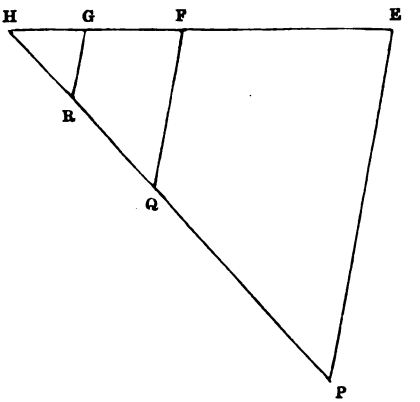
At the top of next page is a slide diagram, obtained by connecting the string to the slide cross-head of the Bee. The whole length of the figure is the same as the travel of the slide. If not, a plan must be adopted to be afterwards explained. When the pencil is at *d*, the slide is at the lowest point, and the vacuum is very good, as the slide rises till the pencil comes to *e*; but since we know *à priori*, that the vacuum remains good in the engine till the



cushioning commences, therefore when the slide has risen from *d* to *e*, the cushioning commences; the cushioning continues as the slide rises till the pencil arrives at *f*, when fresh steam enters, and after this epoch the slide still rises till the pencil has reached the point *h*. As the upper line is not so marked in its character as the lower one, we shall not say any thing of the downward stroke. Through the points *d*, *e*, *f*, &c. draw the vertical lines *Ad*, *Be*, *Cf*, *Dh*, cutting the atmospheric line in *A*, *B*, *C*, *D*, and the horizontal line *E H* in *E*, *F*, *G*, *H*. Suppose *E H* to be the nozzle of the steam-port, on which the face of the steam-slide moves (the cylinder being for convenience of illustration supposed to be lying *horizontally*). Then, since when the pencil comes to *e*, the cushioning commences, *F* must be the upper edge of the port. Take *FF'* equal to the depth of the port (which we will suppose known). Again, since when the pencil is at *d* the slide is at the lowest, therefore we must suppose it to have started from *E*; and consequently, at starting, the upper edge of the slide was below the lower edge of the port,

the space $F'E$. When the *upper* edge of the slide arrives at G, fresh steam enters; in other words, the lower edge of the port is at F', and therefore the depth of the slide-face is $F'G$. Moreover, since the slide still rises through the space HG, HG will be the greatest amount of opening for steam. The successive positions here spoken of are laid down in the figures under the line $E\,H$. $F\,F'$ is the depth of the port. In 1, the slide is at its lowest; in 2, the cushioning is commencing; in 3, the steam is about to enter; in 4, the slide is at its highest.

When the travel of the slide is greater or less than the breadth of the diagram; let HE be the breadth of the



diagram, as in the last paragraph; from H draw HP, making any finite angle with HE, and equal to the travel of the slide. Join PE, and through F and G draw FQ, GR, parallel to EP, and then proceed with the line HP, as in the last paragraph with the line HE, considering Q to be the upper edge of the steam-port, &c.

Does the piston diagram necessarily return into itself, and form a closed figure, as in the preceding diagrams?

This only happens because the Indicator-barrel contains the spring which, as has been stated, draws back the barrel

directly the string relaxes. But we can by a different arrangement produce a figure, of some value, in which the curve proceeds continuously in one direction, and which, therefore, we shall call the "continuous diagram." Let the spring fitted to the traversing cylinder, for bringing it back, be taken out, and also the stop that prevents the cylinder from going too far; because our object is to let the barrel revolve freely. The clasp, by which the paper is usually secured, must also be taken off, and the paper must be secured by turning it over the top of the cylinder, and be folded in such a manner that the pressure of the pencil will help to keep it down. Let now some part of the engine be selected where a double pulley may be fitted to revolve, one groove of the pulley having about the same diameter as the pulley attached to the barrel, and the other to the diameter of the paddle-shaft. A string must be passed round this latter pulley and the shaft, and they will revolve in the same time. Another string must be passed round the pulley of the barrel and the smaller of the two pulleys; and then the Indicator-barrel will revolve nearly in the same time as the engine shaft. And if we suppose the shaft to be revolving uniformly, which it will be nearly, especially where there are two engines, the barrel will have an uniform motion in one direction. If the pencil be put to the paper, as in ordinary cases, when the Indicator-piston is at the lowest, it will commence tracing its curve. It should be allowed to remain for one entire revolution, and longer if convenient, provided one line do not interfere with the other in going twice over the paper.

The chief practical utility of these diagrams is, that they serve to shew *the rate* at which the steam-pressure increases or decreases. It will be observed by the continuous diagram, Plate I. fig. 2, that the steam-pressure does not increase instantaneously, as many suppose, and

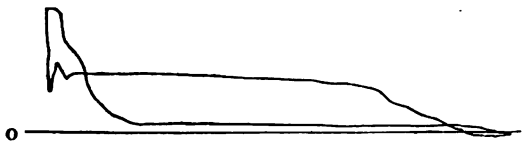
as the common diagram would lead us to believe. The vacuum commences at *D* and continues to *E*, the cushioning from *E* to *A*; the fresh steam enters at *A*, and causes the pencil to rise till it reaches its highest at *B*.

The diagram in page 26 is rounded off at the upper left-hand corner; how do you explain this?

If we examine this diagram by any of the previous tests, we shall find it presents a difficulty not easily surmounted. For in all former cases we can only correct a defect in this corner at the expense of the lower left-hand corner. As the Indicator persisted in giving this outline, and all attempts according to the foregoing principles (by altering the set of the slides, &c.) failed, it was at length proposed to examine the steam-piston itself; and accordingly, steam was let in at the lower port, and the cock of the grease-cup opened, when it was discovered that the piston was not steam-tight in the cylinder; and therefore, although when the engine was working the first impulse of the steam sufficed to drive the pencil up, yet as soon as the piston had got into motion, the escape of steam by leakage did not allow the pencil to rise so rapidly as it otherwise would have done.

If an engine be worked without condensation, what would be the nature of the diagram?

It is evident that no part of the diagram can be below the atmospheric line; for the pressure can never be less than that of the atmosphere. And since the steam has not a free escape into the air, but is obliged to force open the foot-valve and delivery valve, and make its way through the air-pump bucket, the resistance it meets with will cause the pressure to be greater than that of the atmosphere. Engines, whose steam-pressure is not considerably greater than that of the atmosphere, cannot be worked on the high-pressure principle. The diagram in next page was taken from H. M. S. Bee, whose boiler-pressure is 7lbs. In high-pressure engines,



the diagram will be similar to the above; because the steam having to escape by the blast-pipe, is pent up, and causes the lower part of the diagram to be above the atmospheric line. In general, the steam and vacuum lines must be worked out separately by the plan proposed in page 29; for it will be observed, that the lines intersect each other in the diagram. The Indicator for high-pressure engines should be made expressly for the purpose; the scale of pounds should have a higher range, but need not go below the atmospheric line.

This curve presents a singular appearance, from the steam and exhaust line intersecting. Since the cushioning begins at the usual place, that is to say, at the same part of the stroke as when used as a low-pressure engine, the steam pent up on the exhaust side, and commencing with a pressure greater than that of the atmosphere, soon surpasses that of the boiler, so that when the port begins to open, the pressure suddenly falls. Again, when the entering steam is cut off, the pressure gradually falls, and before the end of the stroke it is less than that of the eduction; and when opened again to exhaust, steam enters from the condenser, and the loop of the right-hand corner is formed.

THE DYNAMOMETER.

This instrument has been introduced into screw-vessels, for the purpose of enabling the engineer to record the exact amount of pressure given off by the screw-shaft, and, consequently, the force the engine, by means of this instrument, is exerting to propel the ship. It is merely a lever, or a combination of levers; the shaft pressing near the fulcrum, and the farther end of the lever, or combination, being attached to a Salter's spring-balance. In the diagram, Plate I. fig. 3, *AB* is the screw-shaft pressing as it revolves against a movable pin which is contained in the plomer-block at *C*, and can slide freely backwards and forwards; *DE* is the lever, having the fulcrum at *D;* the pin at *C* presses against a knife-edge on the lever, as is seen in the figure. The rod *EF* is connected with the spring of a Salter's balance, which cannot be seen in the figure, but is concealed from sight by the cylindrical barrel *IK; F* is also attached to the rod *GH*. This rod, as we perceive, has several grooves in it, so that the small fork carrying the pencil (*p*) may be brought in contact with more than one part of the barrel in succession, if desirable.

The barrel is made to revolve by means of a strap *a b*, connecting it with the screw-shaft; and it will be seen by the figure, that there are pulleys of different sizes connected with the bulk-head at *M*, and the shaft at *N*, by which the motion of the cylinder can be regulated, and be made quicker or slower at pleasure. The curve will

evidently be somewhat similar to the *continuous Indicator diagram*, consisting of a series of undulations according to the force of the steam and its action on the propeller. A zero-line must be got, as in the case of the Indicator. When the Dynamometer is applied to large engines, the levers can be relieved of the pressure of the shaft; and this being accomplished, the index of the spring-balance will stand at 0, when the zero-line may be traced. The balance will also give the scale of pounds. After the diagram is traced, draw a series of equidistant lines at right angles to the zero-line, as in Plate I. fig. 4, which represents a Dynamometer diagram taken on board H. M. steam-vessel Rattler during her trial with Alecto, the dimensions being reduced one-half. The distance between the curve and zero-line must be measured and compared with the scale of pounds on the balance. Let this be registered on the diagram in its proper space. The sum of all these is then to be taken, and divided by the number of spaces taken into account. Thus we shall obtain the mean force of the lever on the spring of the balance; let this be multiplied again by the *leverage* of the Dynamometer, and the result will be the pressure of the screw-shaft on the Dynamometer, and, therefore, on the vessel.[1] To obtain the leverage, if the lever be compound, multiply together all the long arms (measuring from the fulcrum), and divide the product by all the short arms multiplied together (measuring also from the fulcrum).

How is the horse-power of an engine to be found by the Dynamometer?

[1] A doubt has been expressed by some as to whether this is really the force exerted by the shaft on the vessel, on account of the shaft acting on a lever that yields to its force; but independently of the fact that none of the thrust can be lost, it is clear that the thrust at *C* is equal to the thrust at *D* and that at *E*, and these are the two forces acting on the vessel.

Having found the number of *pounds* pressure exerted by the screw-shaft, multiply it by the speed of the ship in knots, and the product by 6080 (the number of feet in a knot); then divide the result by 60 (the number of minutes in an hour), and by 33,000, and the quotient will be the horse-power.

Or the work may be shortened, thus:

Multiply the number of pounds pressure by the speed of the ship, as before, and this product by ·00307, and the product gives the horse-power.

This, it will be observed, is the *effective* horse-power after making allowance for friction and loss by useless resistance.

The diagram before referred to will elucidate the process of working out the result. This was taken simultaneously with two others; and the mean of the three pressures was 41·309 lbs. Multiplying by the power of the system of levers, the result was 8086·4 pounds (the pressure exerted by the screw-shaft).

The speed of the ship was 9·893 knots.

Hence $8086{\cdot}4 \times 9{\cdot}893 = 79998{\cdot}7$.

And $79998 \times {\cdot}00307 = 245$ nearly; the horse-power required.

The horse-power by Indicator at the same time was 465·6, shewing a loss of 220·6 by friction, resistance, &c.

THE END.

LONDON:
PRINTED BY LEVEY, ROBSON, AND FRANKLYN,
Great New Street, Fetter Lane.

